Modeling of the Shallow Water Reverberation for ONR ASIAEX Experiment

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LONG-TERM GOALS

The long-term goal of the research is to better understand the mechanisms of bottom reverberation in shallow water, and enhance modeling of the shallow water reverberation.

OBJECTIVES

The objective of this research is to study bottom reverberation as observed during the recent ONR Asian Seas International Acoustics Experiment (ASIAEX), with emphasis on careful extraction of bottom scattering strengths as a function of frequency and scattering angle, with the ultimate goal to infer scattering mechanisms responsible for low frequency bottom scattering in shallow water, and to improve modeling of the low-frequency reverberation in shallow water.

APPROACH

Proposed approach consists of
1. Using a normal mode approach based on the inversion of the environmental parameters [1] to remove propagation effects from the received signal.
2. Using Wakeley source model [e.g., 2] to provide source function.
3. Using modeling and analysis of data collected during quiet sea state and during high sea state in order to separate bottom and surface contributions to the reverberation.
4. Using empirical and model-based analysis of the reverberation frequency and angular dependence in order to separate bottom interface and subbottom scattering, and overall better understand reverberation mechanisms.
5. Using VLA data to infer angular dependence of the scattering strength.

WORK COMPLETED

During GFY03 Peter Cable (BBN), Yevgeniy Dorfman (BBN), David Knobles (ARL/UT) and Tomas Yudichak (ARL/UT) have collaborated, working with the IAO reverberation data and with ASIAEX ECS transmission data obtained by Jim Miller, Gopu Potty (URI), and Peter Dahl (APL/UW), as well as with other East China Sea data sources.

Monostatic reverberation data were inverted to infer empirical bottom scattering strength (SS) as function of frequency using environmental inputs generated by ARL/UT. Empirical data collected from 1 kg shots deployed during high sea state were initially analyzed. Data from 1 kg shots deployed

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14. ABSTRACT
The long-term goal of the research is to better understand the mechanisms of bottom reverberation in shallow water, and enhance modeling of the shallow water reverberation

15. SUBJECT TERMS

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during low sea state are currently being analyzed in order to assess potential contribution of ocean surface scattering to the reverberation.

Uncertainties in the experiment and inversion procedures were analyzed in order to provide error bound on the extracted scattering strength. Issues considered included:
1. Uncertainty in the inferred environmental inputs used for forward transmission loss modeling.
2. Uncertainty in the wideband explosive source level.

Data collected by the VLA were analyzed in order to infer angular dependence of the scattering strenth. Two approaches to infer scattering strength angular dependence were exercised:
1. VLA data were beamformed yelding scattering strength as a function of VLA steering angle. Raytracing was used to relate VLA steering angle to the scattering grazing angle on the bottom. Implied in this method is that scattering happens in the far field of the array. While sometimes true, this assumption is often violated when large array is used in shallow channel.
2. Alternatively, numerical normal mode code was used to compare field distribution on the VLA with that which would be caused by a point source positioned at the scattering range (source depth was varied, directive source can be simulated by coherently processing contribution from several sources). This approach may provide valuble (albeit indirect) information of the scattering strength physics, such as angular dependence of the scattering strength and separation of surface, bottom interface and subbottom inhomogeneities to the overall reverberation.

An initial report on the frequency dependence of East China Sea bottom scattering strength and effects of source uncertainty was presented at the ASIAEX International Symposium in Chengdu, China, in October 2002. In addition, three papers were presented at the First Pan-American/Iberian Meeting on Acoustics in Cancun, Mexico, 2-6 December 2002: “Comparison of East China Sea low frequency bottom scattering strength determinations” (Cable *et al*,. J.Acoust Soc. Am.**112**(5), Pt.2, 2362 (2002)]); “Analysis of time series data in the East China Sea generated from explosive sources” (Knobles *et al*, J.Acoust Soc. Am.**112**(5), Pt.2, 2361 (2002)]); and “Mechanisms for the Asian Sea International Acoustics Experiment East China Sea reverberation measurements” (Dorfman *et al*, J.Acoust Soc. Am.**112**(5), Pt.2 2254 (2002)).

RESULTS

Empirical scattering strength was inferred from the reverberation data, error bound of the scattering strength was also determined. Initial results for the frequency dependence of the scattering strength indicate that it is very shallow (almost flat) below a few hundred Hz, and very steep (close to F^2 - F^3) above a few hundred Hz, with a very sharp transition. This may suggest a change in the mechanisms of the reverberation, with the low-frequency part of the curve being dominated by subbottom scatterers [3], and the high frequency part of the curve dominated by contribution of the small scatterers on the interface.

Initial results of the angular distribution of the scattering strength at frequencies above a few hundred Hz indicate that it may be consistent with a point omnidirectional source positioned at or near the bottom interface, consistent with interface contribution being dominant at this frequencies. Interestingly, if VLA data are beamformed and beam power is converted to angular dependence of the bottom scattering strength, resulting angular dependence is very close to that predicted by Lambert Law (see Fig. 1), which (except for the level) is also consistent with a combined effect of a large group

of uncorrelated small scatterers. Work is underway to further analyze these results in order to better understand mechanisms of the bottom reverberation.

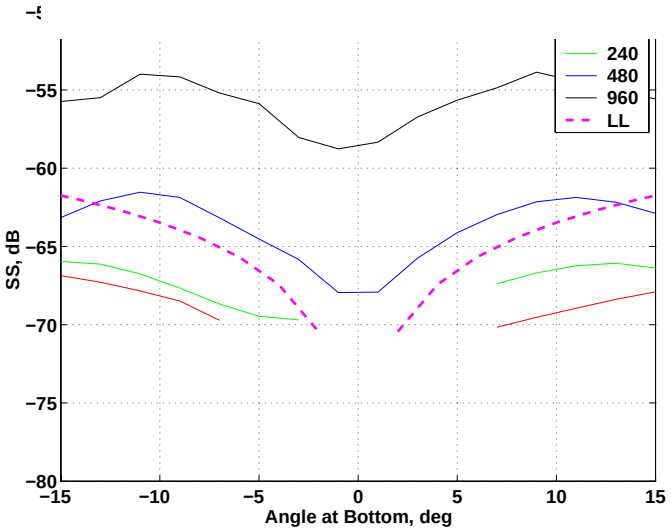

Fig. 1. Angular dependence of the scattering strength (dB) as function of scattering angle at the bottom (shown in degrees). Red, green and blue lines: 120, 240, 480 and 960 Hz, respectively. Dash magenta line: Lambertian angular distribution (dB//arb.ref.)

IMPACT/APPLICATIONS

Bottom reverberation is a major factor limiting active sonar performance in shallow downrefracting channels. Better understanding and predictive modeling of bottom reverberation will aid in sonar design, optimization, and performance and tradeoff studies.

RELATED PROJECTS

This research is being conducted jointly with David Knobles, ARL/UT and with Peter Cable (BBN). In addition, the ASIAEX long range reverberation studies of Renhe Zhang and Ji-Xun Zhou were used in this present research.

REFERENCES

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